Major Daniel STECH
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London NW1 5TH
UNITED KINGDOM

24 October 1995

Dear Major Stech,

please find enclosed a Final Report on a Research Contract SPC-94-4102 "Growth of GaSe Crystals". One can find in Report some physical parameters of grown crystals (15 items) with different thickness, required by Contract.

Kind regards

Professor Kerim ALLAKHVERDIEV
Principle Investigator

Enclosure: Report on -3- pages
Figure of location of 15 crystals in 2boxes.

Final report is acceptable —
Please make final payment.
J. Stech
12 Nov 95

REPORT DOCUMENTATION PAGE

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7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

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13. ABSTRACT (Maximum 200 words)

This report results from a contract tasking Qa Rel Associates as follows: Grow GaSe crystals as described in the attached proposal dated 1 August 1994. Samples should be single crystals of varying thickness with faces perpendicular to the c-axis. The samples should have nominal area of at least 10 x 10 mm.

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24 October 1995

FINAL REPORT ON A RESEARCH CONTRACT
SPC-94-4102 "GROWTH OF GaSe CRYSTALS"

According to the requirements of the Contract single crystals of layered compound GaSe (Gallium Selenide) were grown by modified Bridgman method. Characterization were made using the different techniques.Among them are:

DTA (Differential Thermal Analysis) of polycrystals
X-ray powder diffraction measurements
Optical characterization in polarized light
Electron scanning microscopy
Optical absorption in the range of the exciton
Transmittion measurements in the spectral range 0.7-20 μm
Long wavelenght far IR reflection in the restrahlen bands
Raman scattering spectroscopy
Maker fringe pattern of SHG signal

The anlysis showed that a content of grown crystals is close to stechiometry. The position of excitonoc absorption (n=1) at 300 K at 620nm and at 4.2K at 587nm in accordance that the crystals belong predominantly to epsilon polytype (space group D3h1,abscence of the inversion symmetry,two layers per primitive unit cell). Simultaneous activity of the low-frequency rigid-layer mode $E'(20cm^{-1})$ in the IR and Raman scattering spectra (excited with 6471 Å line of Kr-ion laser) also says in a favour of fact, that grown crystals belong to non-centrosymmetric epsilon modification(1).
Transmission measurements in the IR range showed,that all grown crystals are transparent in the region 0.7-18 μm, having absorption coefficient less than 1 cm^{-1}. Good optical quality of supplied crystals was also proved by measuring a Maker fringe pattern of the SHG signal excited in crystals with 1.579 μm line of Quanta-Ray RS-1 Raman Shifter (Spectra Physics) at room temperature. Observed fringes were clearly resolved and symmetric to "+" and "-" direction of rotation relative to optical C-axis.

Peak intensity damage at 10.6 μm of CO2 laser averaged for 5 crystals with thicknesses 5mm was about 30MWt/cm2 at frequency repetition 20Hz.

One can summurize the physical properties of supplied crystals as follows:

Crystal structure:	space group D3h1 (P6m2) a=3.757 Å c=15.946 Å
Free carrier concentration:	$p \approx 8 \times 10^{14}$ cm^{-3}
Mobility:	$\mu \approx 30$cm^2/Vs
Transparency range:	0.7-18 μm
Forbidden gap:	E=2.020eV
Position of the ground state of direct free excitons:	2.001eV
Direction of the optical C-axis:	always perpendicular to the cleavage plane
Peack intensity damage at 10.6 μm of CO_2 laser at f=20Hz:	about 30MWt/cm^2
Nominal area available perpendicular to optical axis:	averaged for supplied crystals 13x13mm, not less than 10x10mm

Grown crystals are supplied in two different small boxes.They are numbered trough 1 to 12 (see supplied figure). The crystals N1-4 are in a black thick box. The crystals N5-12 are in a thinner box. Number on top of each crystal is their weight in gramms(for example 363660 for crystal N1 means 36.3660gramms).Numbers inside-shows the thickness in mm.

The crystals numbered 1 and2 are supposed to be cleaved each for two crystals:

N1 for crystal with t=15mm and for cyrstal witht=7mm

N2 for crystal with t=10mm and for crystal with t=7mm

Crystals N1 and N2 were not cleaved and lefted for deceision and suitability of user,if they need the crystals with freshly cleved surface or with thickness between 18 and 0.5mm.

But if we concider that N1 and N2 are cleaved,then the numberes on the left corner of figure shows the number (right row) and the thickness (in mm,left row) of supplied crystals.For example (6-1 means:

one crystal with thickness 6mm; 15-2 : two crystals with thickness 15mm

Taking into consideration such a classification all the crystals required by Contract are supplied:

1 with t=6mm
2with t=7mm
2 with t=8mm
} all can be attributed to the crystals with t=5mm

3 with t=10mm
2 with t=12mm
} all can be attributed to the crystals with t=10mm

1 with t=14mm
2 with t=15mm
1 with t=18mm
} all can be attributed to the crystals with t=15mm

For each crystal thickness is shown in the direction of the optical axis C perpendicular to the cleavage surfaces with nominal area averaged 13x13mm and not less than 10x10mm, as stated in Contract.

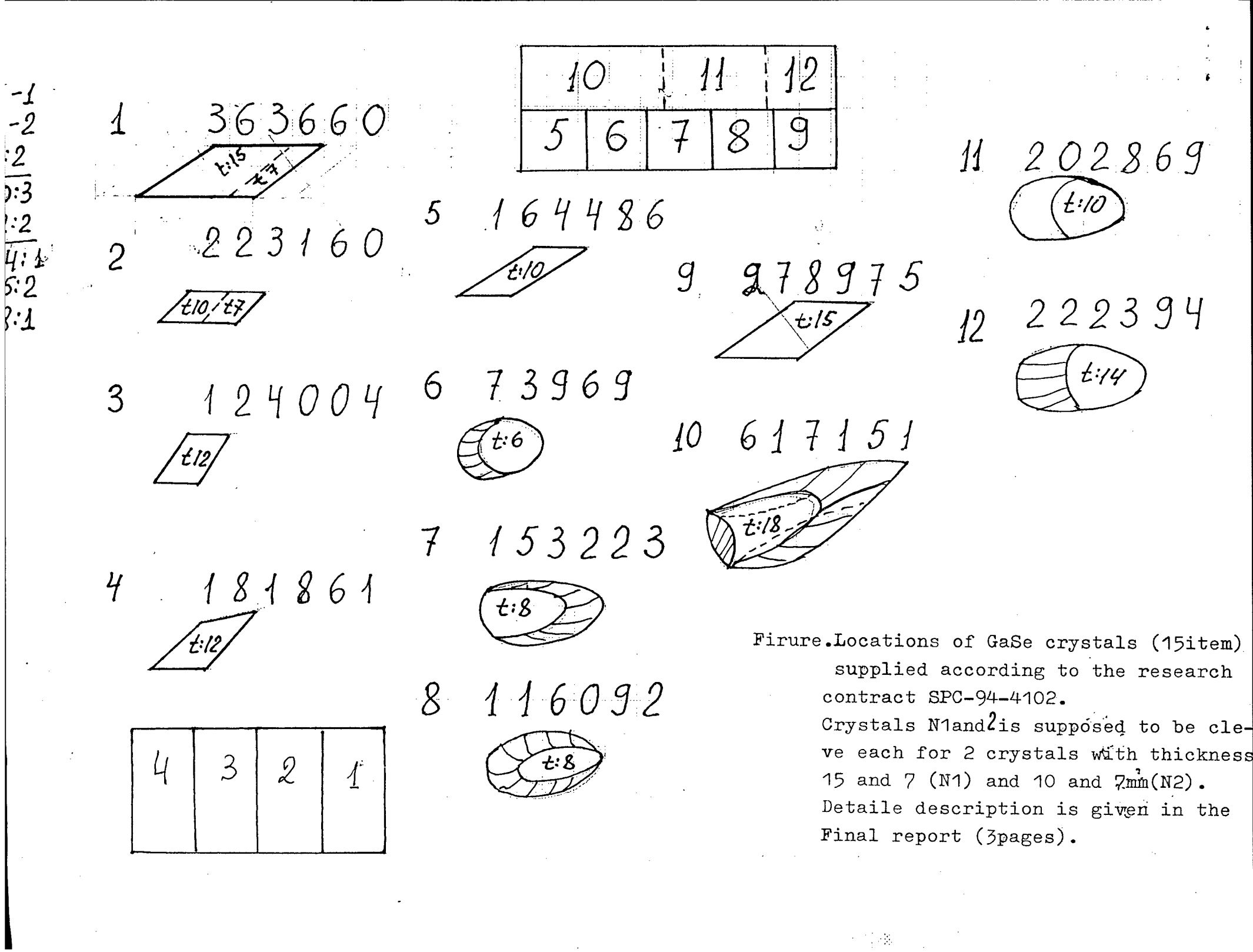
Common weight of supplied crystals : 272.1843gramms.

REFERENCES:

1.Landolt-Burnstein,Zahlwerte und Funktionen aus Naturwissenchaften und Technik,Neu Serie Gesamtherausgabe:K.Hellwege,O.Modelung.Gruppe 3: Kristalle und Festkorperphysik.Band 17, Halbleiter, Springer,Berlin, Heidelberg, New York, Tokyo, 1983, p.530.

2.E.Salaev, K.Allakhverdiev "Dynamic and Static Nonlinear Effects in GaSe-Type Layer Crystals", Monography (in Russian), Elm,Baku 1993,p.23 p.231

Prof.Kerim ALLAKHVERDIEV
Principle Investigator



Firure.Locations of GaSe crystals (15item) supplied according to the research contract SPC-94-4102.
Crystals N1and2is supposed to be cleve each for 2 crystals with thickness 15 and 7 (N1) and 10 and 7mm(N2).
Detaile description is given in the Final report (3pages).